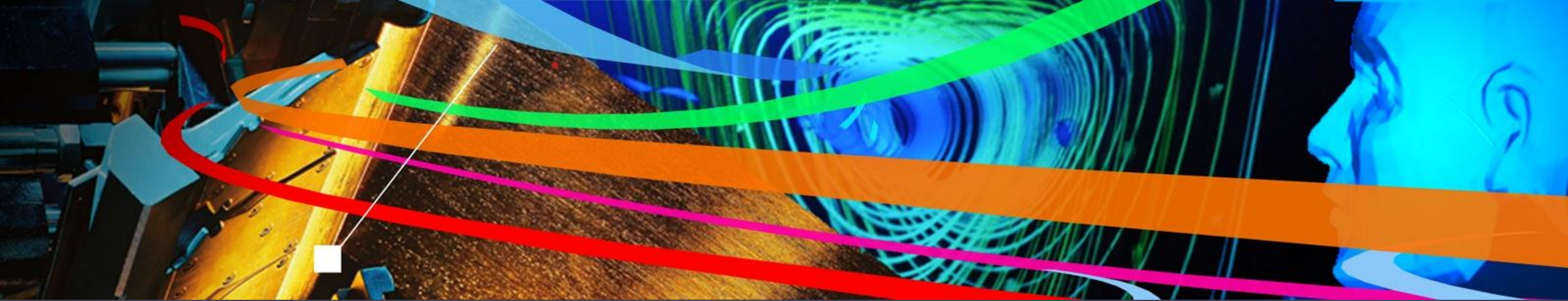

Influence of angularity of coarse fraction grains on internal erosion process

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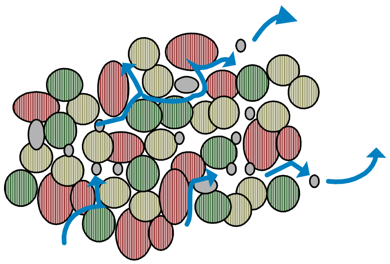
Background

Two types of internal erosion process in uncracked soils:

backward erosion and **suffusion**



Diffuse redistribution of **fine particles** within the soil.

Slight changes of grain size distribution and the **hydraulic conductivity** can evolve notably (Lafleur, 1999; Bendahmane et al. 2008; Marot et al. 2009)

Result from **seepage flow** in the soil pores ➔
great influence of **geometry of the interstitial vaccums**

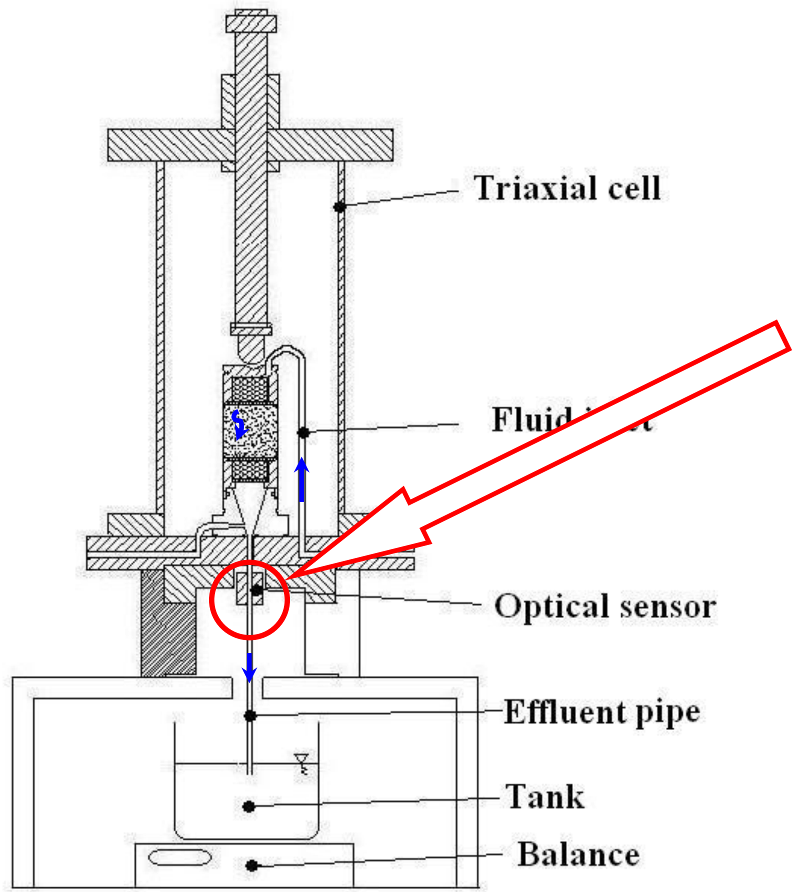
Granular assembly which depends on :

- **grain size distribution** (Wan and Fell, 2008; Li and Fannin, 2008, etc…)
- **mechanical loading conditions** (Skempton and Brogan, 1994; Moffat and Fannin 2011
- **grain shape**

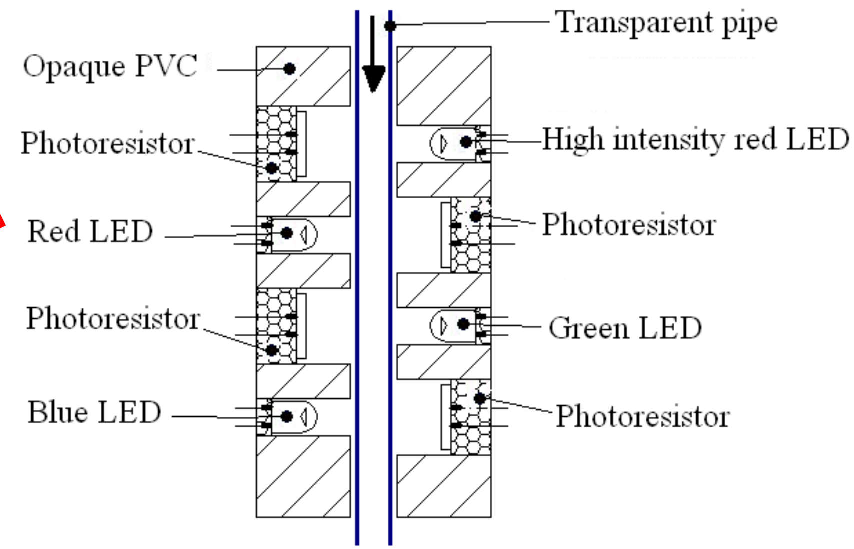
Average pore diameter as a function of shape coefficient (Kovacs, 1981)

Experimental devices

Triaxial erodimeter for **suffusion tests**



Multichannel optical sensor



Small quantity of eroded particles

- measurement of fine particle concentration
- distinction between fines and sand grains

Marot et al. (2011), Canadian Geotechnical J[al]

Optical and **mechanical** methods used for characterization of **grain angularity**

- **Optical microscope** (max enlargement: 40) associated with digital camera
  ➔ Picture analysis

For each tested aggregate

$$Roundness = -\frac{P^2}{4.\pi.A} \qquad Circularity = \frac{1}{n}\sum_{i=1}^{n}\left(r_i - r_{moy}\right)^2$$

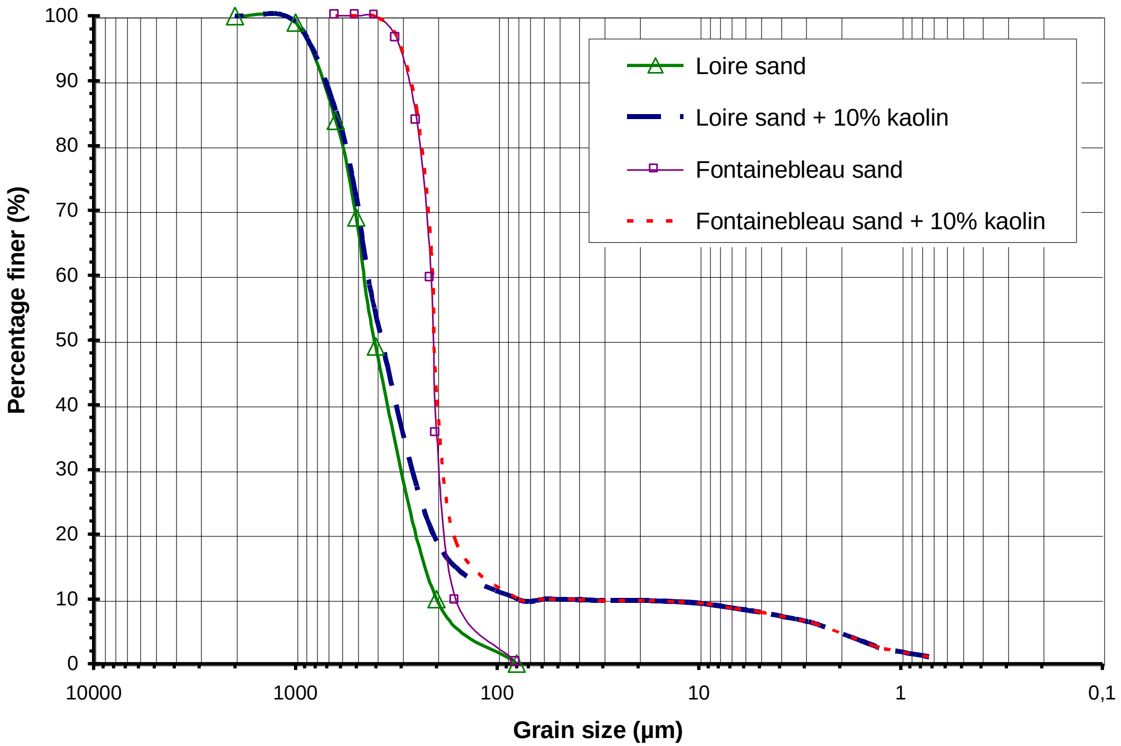
P: perimeter; A: cross section; r_i: radius; r_{moy}: average radius

- **Direct shear box** with density index I_d near to 1 ($I_d = [e_{max} - e]/[e_{max} - e_{min}]$)
  ➔ internal friction angle
- **Angulometer**: standardized funnel, measurement of the gravitating flow duration (E_{cm}). Angularity index I_A: ratio of flow duration of aggregete to flow duration of glass beads

Tested materials

Mixtures of 10% of kaolin and 90% of one of the following aggregates:

- Fontainebleau sand (F) (75μm-425μm, D_{50} = 207μm, uniformity coefficient = 1.33)
- Loire sand (L) (80μm-1mm, D_{50} = 440μm, uniformity coefficient = 3.13)
- Modified Loire sand (LM) composed of grains from L, grain size distribution of F
- Glass beads grain size distribution of F



Laser diffraction particle-size analyzer

Specimen preparation for suffusion tests

Preliminary forming of specimen by single layer semi-static compaction technique

Specimen placed on a 4mm pore opening grid ➔ migration of all particles

Saturation phase with carbon dioxide , demineralized and deaerated water

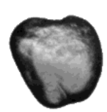
Consolidation (100kPa) ➔ dry density 17.5kN.m^{-3}

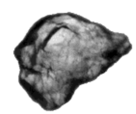
Suffusion test under constant hydraulic gradient

Angularity test results

Circularity very sensitive

Loire sand



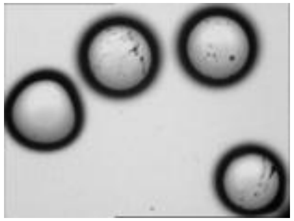
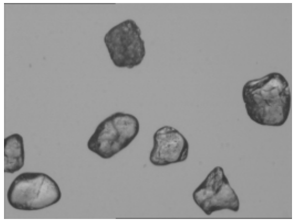
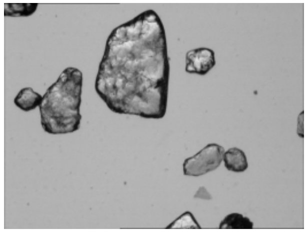


Circularity (µm^2)	25.87	263.03	2 217.32
Roundness (.)	1.19	1.4	1.9
Diameter (µm)	311	478	580

X 85

X 1.6

100 pictures for each aggregate

Glass bead	Fontainebleau (F)	Loire (L)
		

Circularity (μm^2)	3 (22)	63 (52)	178 (305)
Roundness (.)	1.13 (0.06)	1.39 (0.15)	1.42 (0.19)

Mean value (value of standard deviation)

Internal friction angle (°)	30	37	44
Flow duration E_{cm} (s)	17	22	23
Index I_A (-)	1	1.29	1.35

➔ Same relative classification

Glass beads: smallest values

Loire sand: largest values

Fontainebleau sand: intermediate

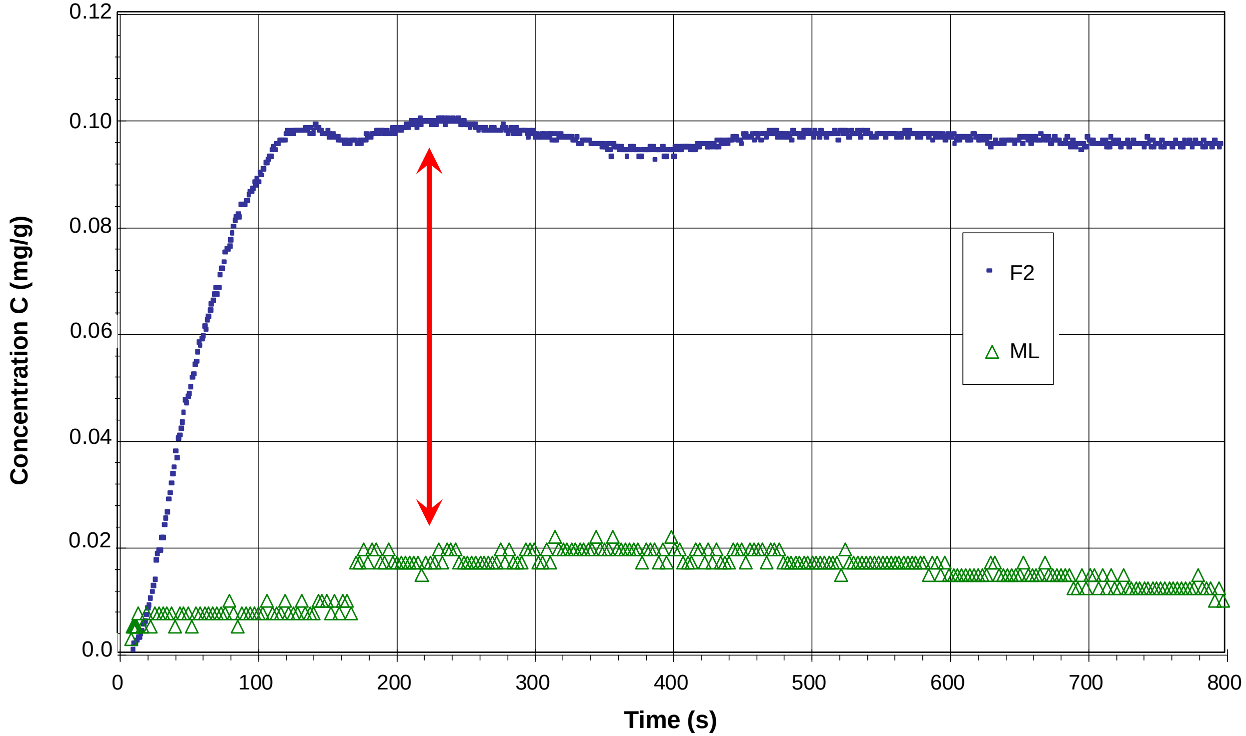
Suffusion test results

Specimen constituted by kaolin and glass beads

➔ instability during saturation phase

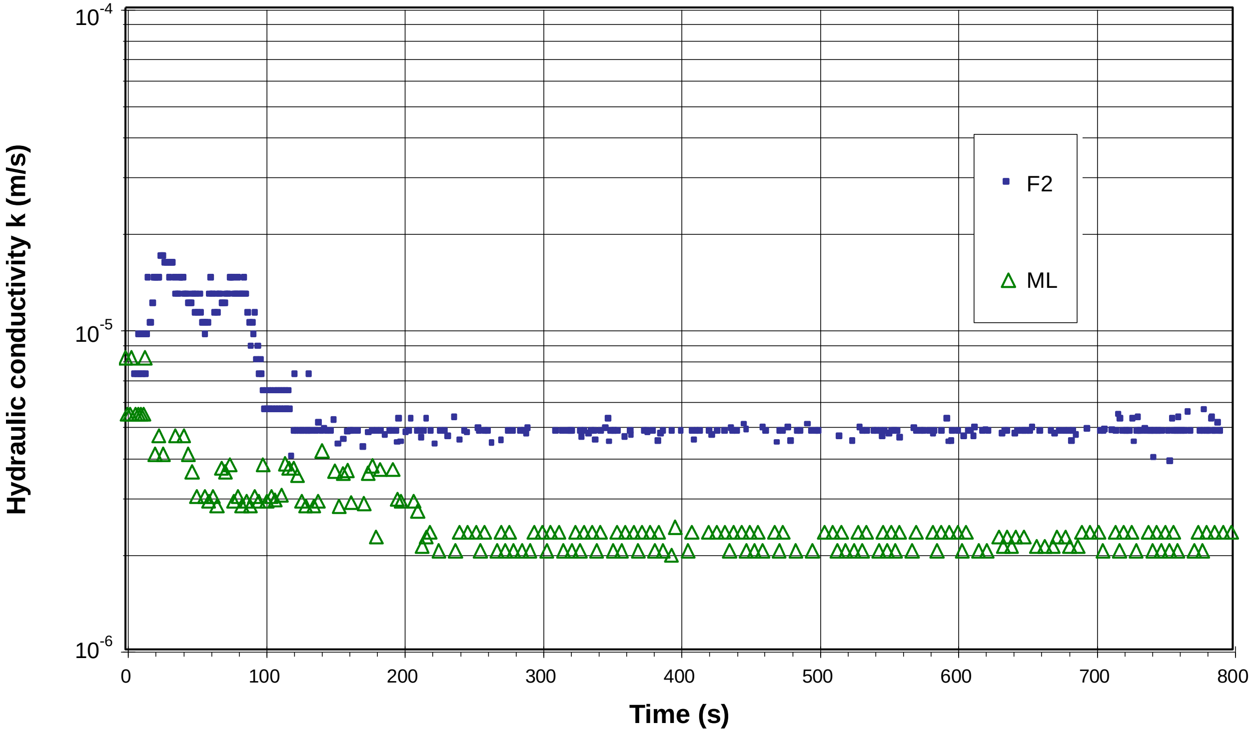
F and ML, **same grain size distribution**, same applied hydraulic gradient **i=0.8**

Clay concentration in effluent



➔ Effect of grain shape: increase of resistance by a factor of 5

Hydraulic conductivity



ML: more important decrease of hydraulic conductivity

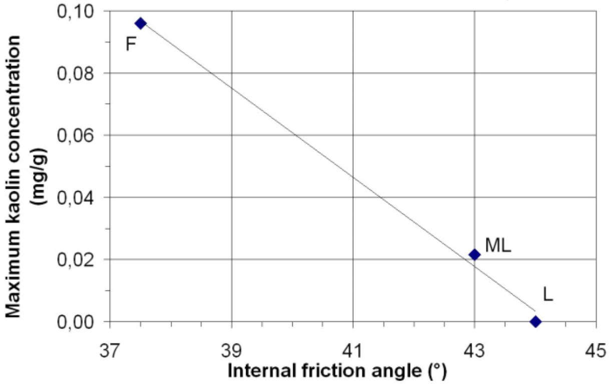
Decrease in hydraulic conductivity attributed to particle filtration

(Reddi et al., 2000; Bendahmane et al., 2008; Marot et al., 2009, 2011)

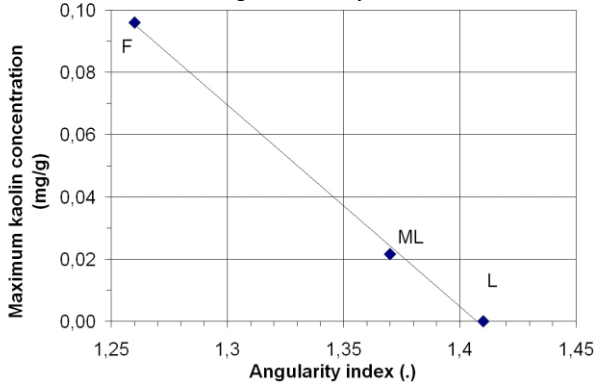
➔ angularity seems to contribute to increase filtration process

Maximum clay concentration versus

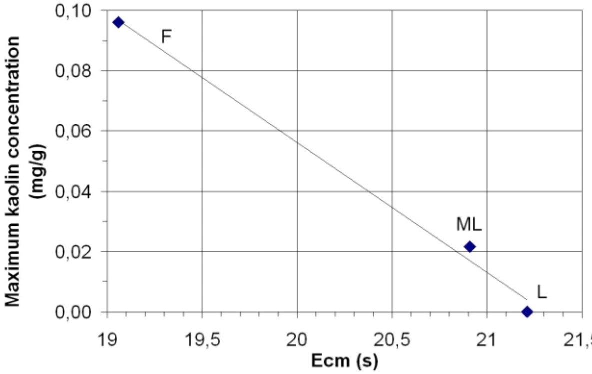
Internal friction angle



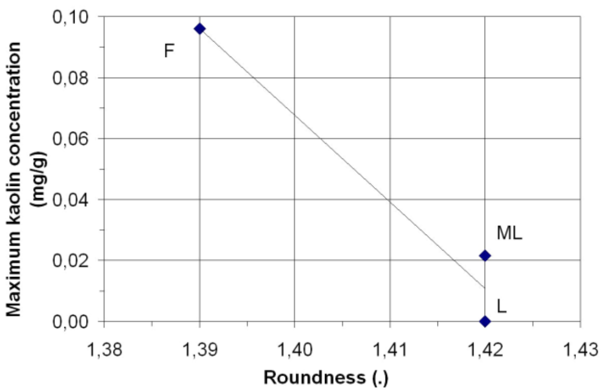
Angularity index



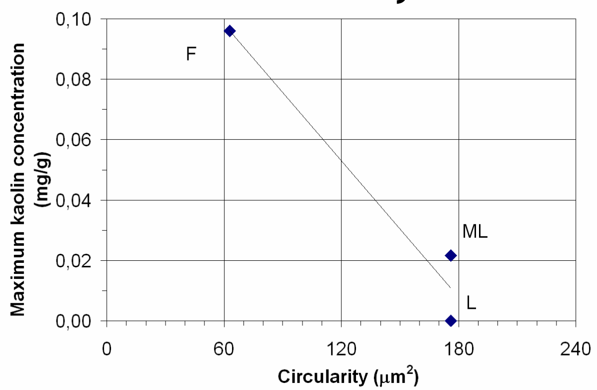
Gravitating flow duration



Roundness



Circularity



Optical parameters no distinction between ML and L,
great values of standard deviation ➔ **Mechanical approach : preferred**

Thank you for your attention!

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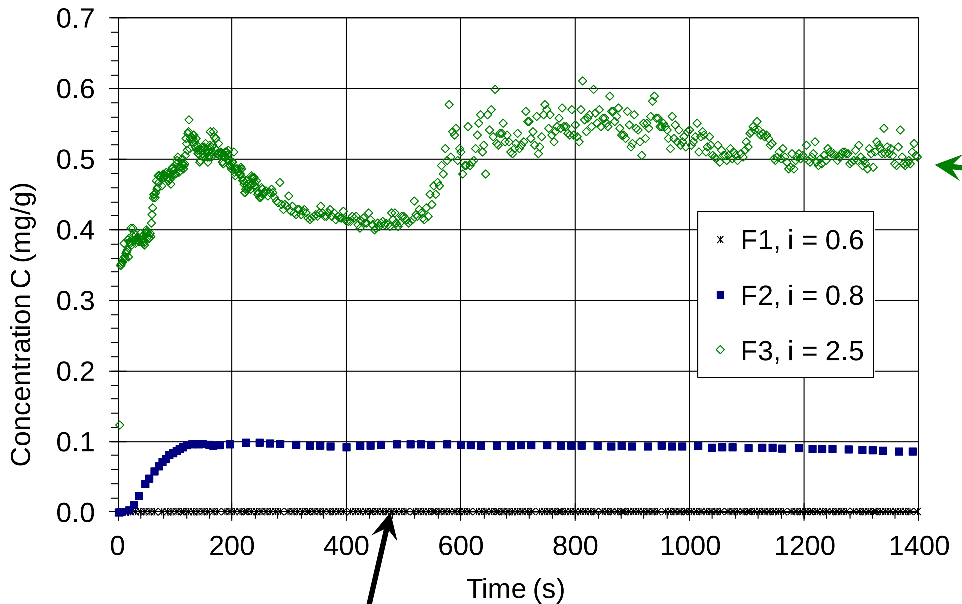
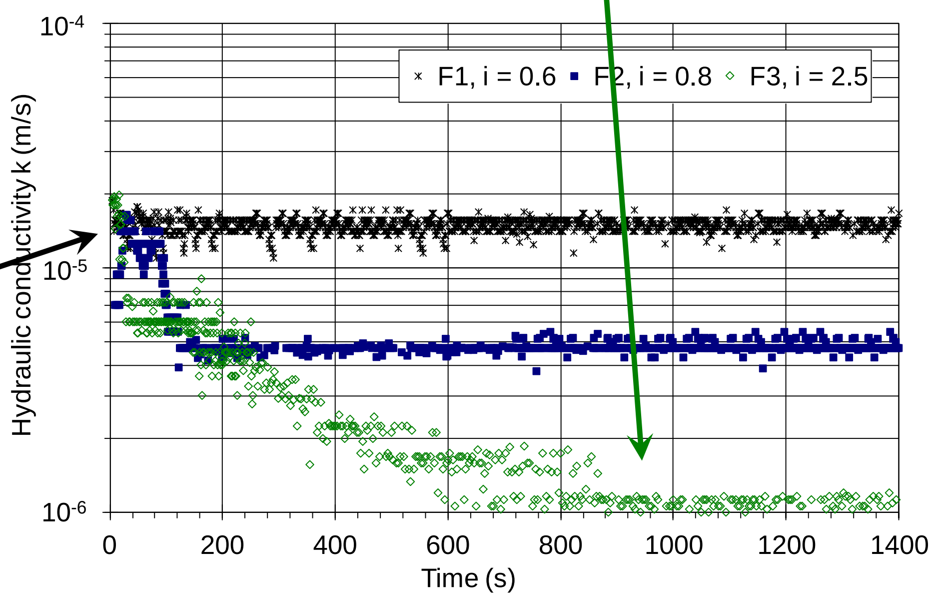
Suffusion test results

Mixture of 10% kaolin and
90% Fontainebleau sand



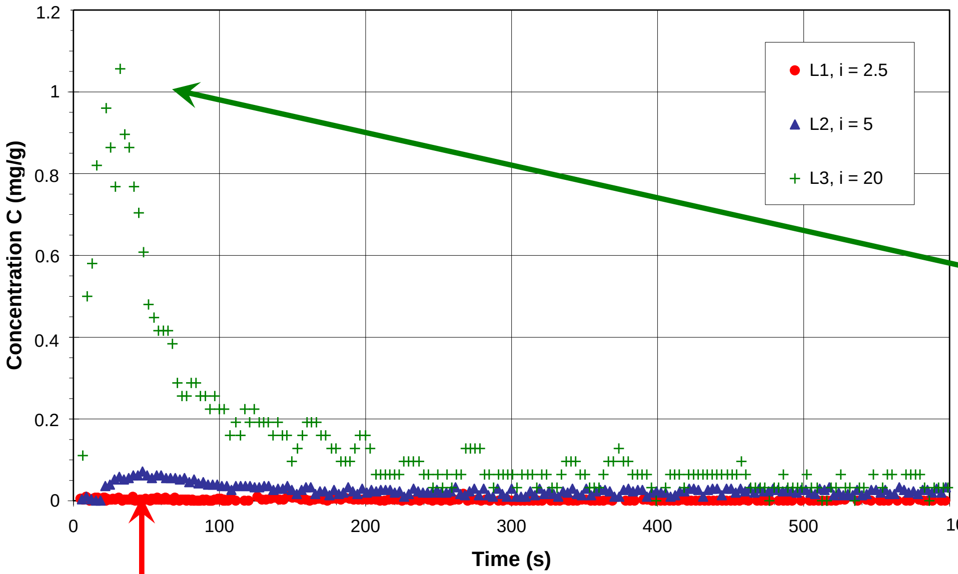
i=2.5
C_{max}=0.55mg/g
hydraulic conductivity decreases from 10^{-5}m/s to 10^{-6}m/s

i=0.6
no erosion
hydraulic conductivity stays constant



Suffusion test results

Mixture of 10% kaolin and 90% Loire sand



i=20
C_{max}= 1.1 mg/g
Important decrease in only a few minutes

i=2.5
C_{max}< 10^{-2}mg/g
hydraulic conductivity decreases from 10^{-5}m/s to 10^{-6}m/s